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Impacts of Partly Cloudy Pixels on Shortwave Broadband Albedo/Irradiance Computations

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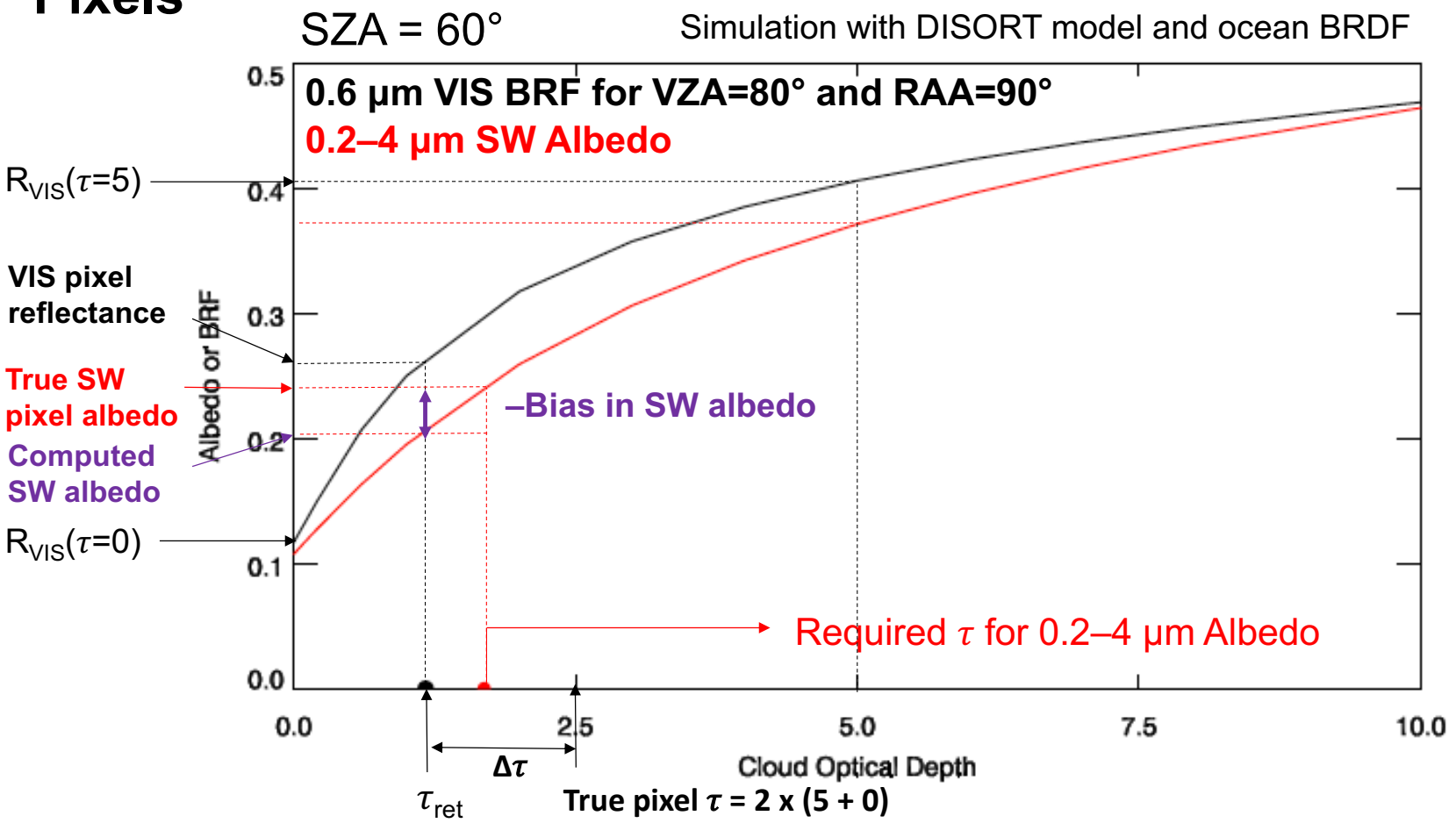
Objectives

- Examine biases in SW broadband TOA albedo/irradiance computations due to partly cloudy MODIS pixels
- Quantify the biases depending on solar/viewing geometry, cloud fraction, and cloud optical depth
- Estimate uncertainties of CERES SW TOA computations due to partly cloudy pixels

An Example of a Negative SW BB Albedo Bias due to Partly Cloudy Pixels

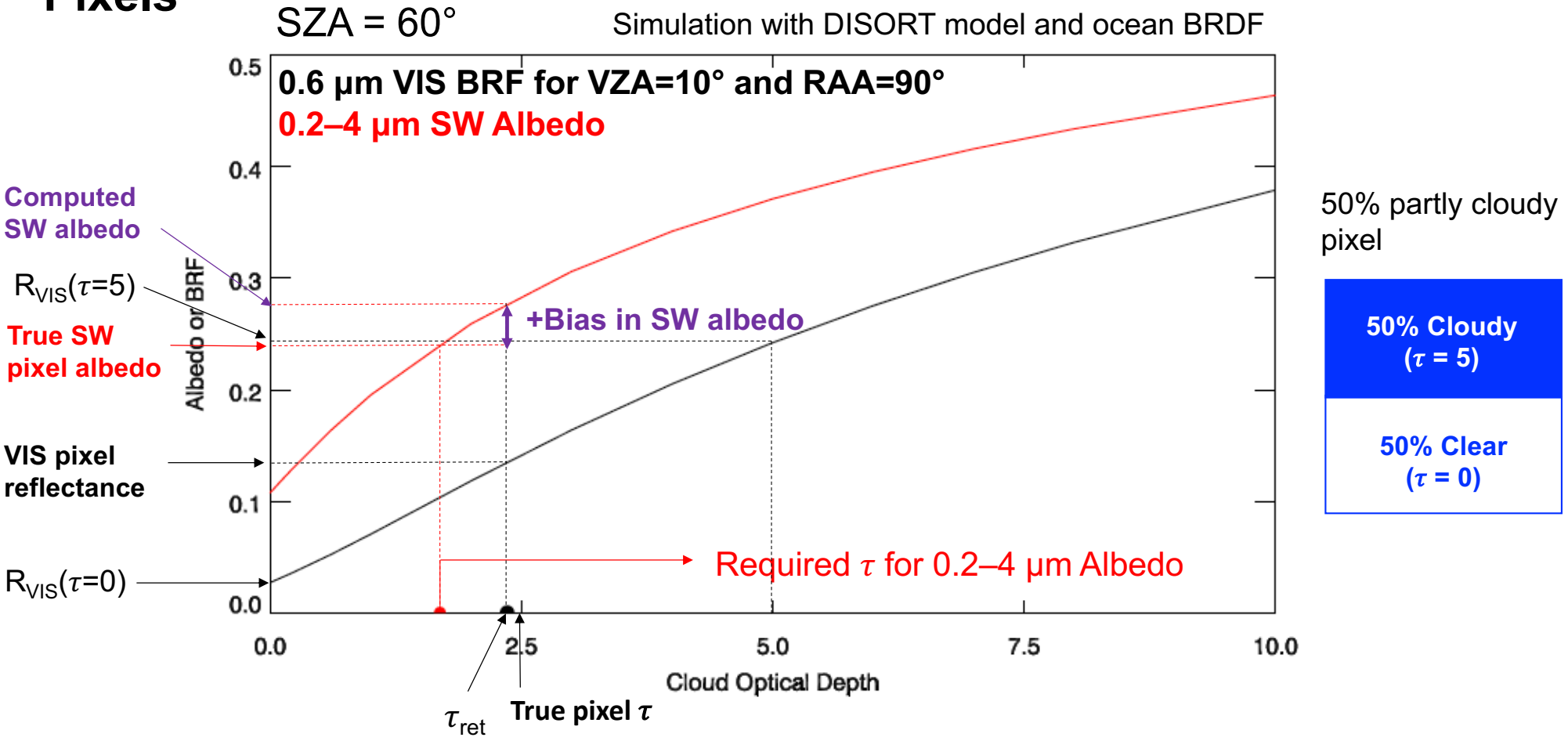


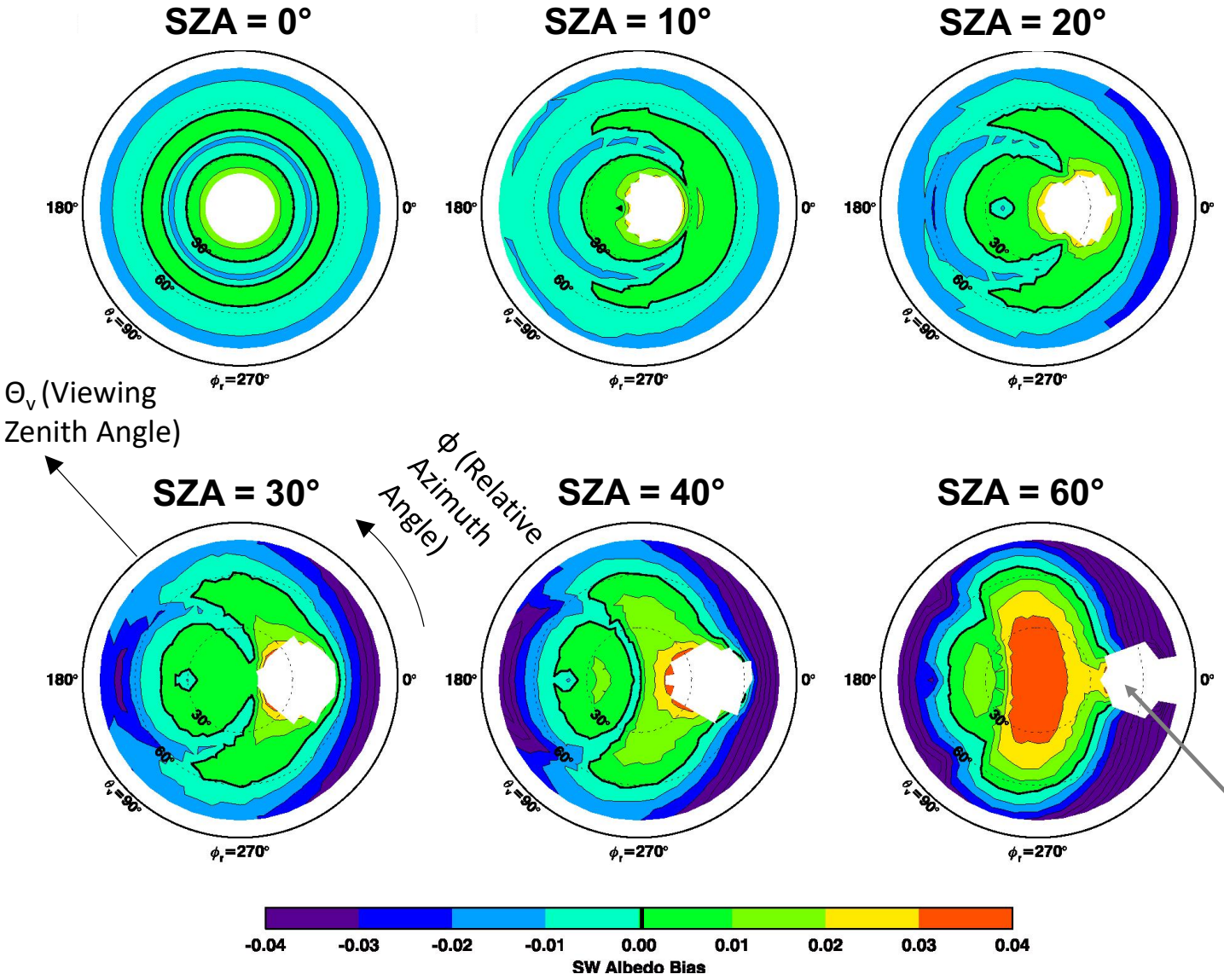
50% partly cloudy pixel

50% Cloudy (τ = 5)

50% Clear (τ = 0)

An Example of a Positive SW BB Albedo Bias due to Partly Cloudy Pixels

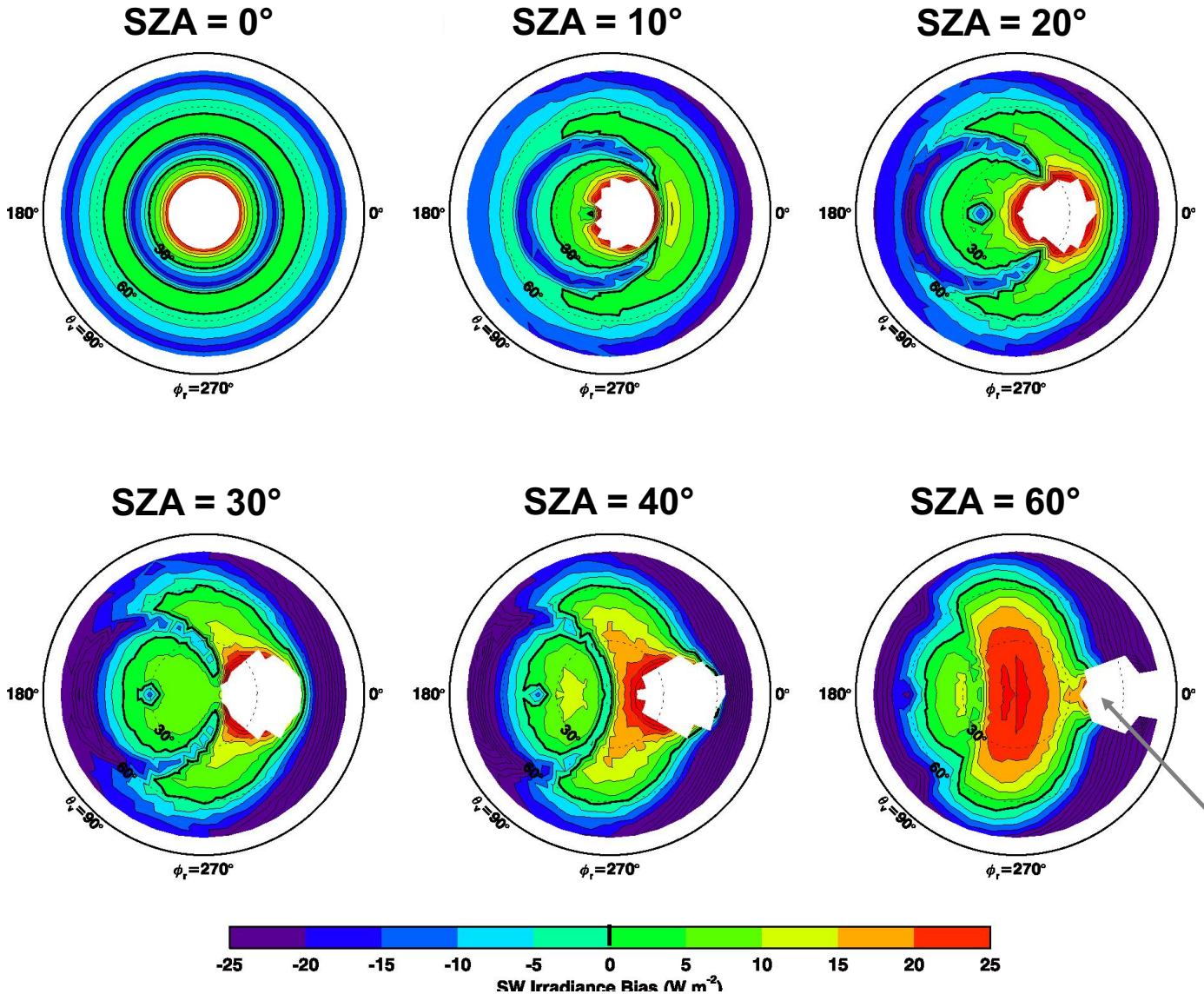




Bias in SW Albedo for a 50% Partly Cloud Pixel with Cloud Optical Depth = 5 When Visible-Channel based Optical Depth Is Used

CERES and MODIS VZAs are < 65° and this means that the biases tend to be positive for large SZAs.

τ retrieval is not possible at sun glint region

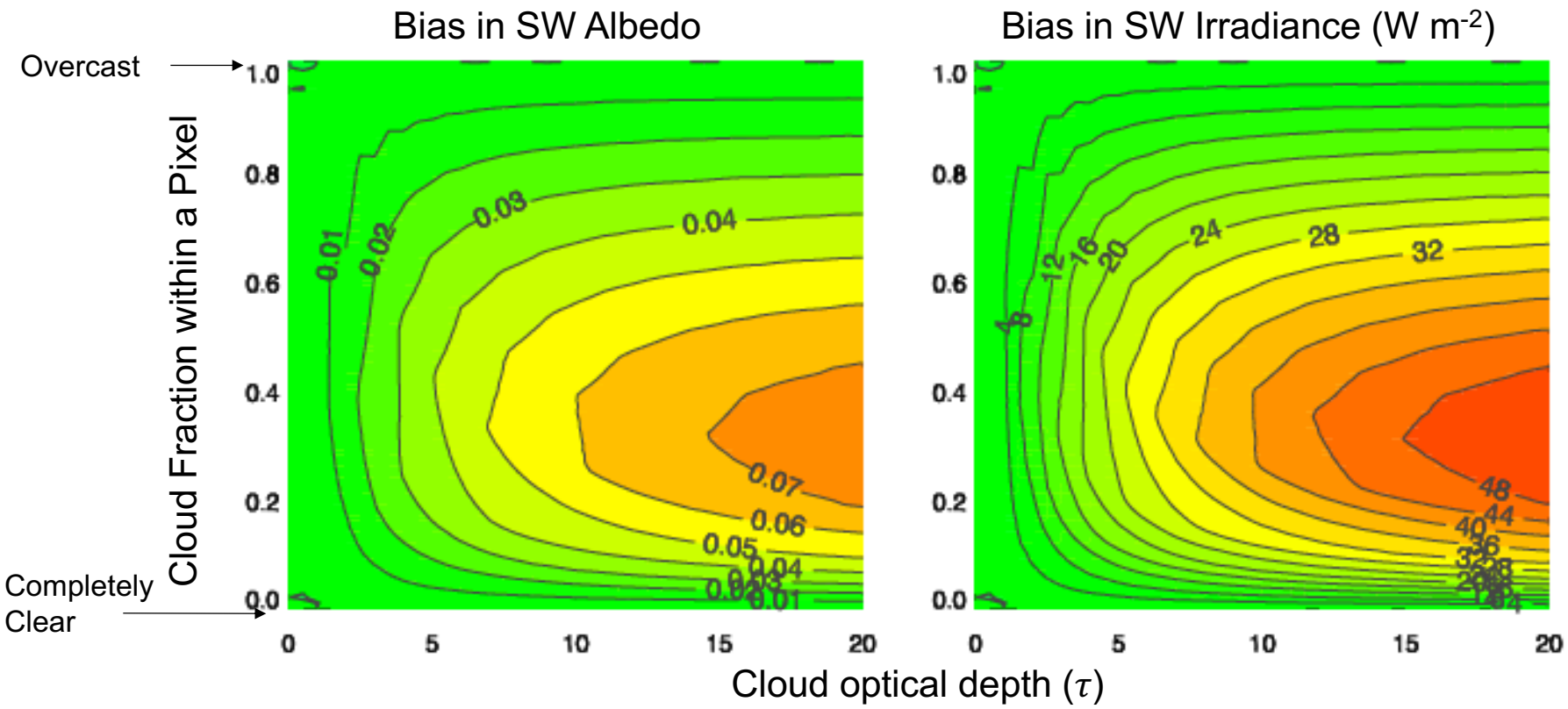


Bias in SW Irradiance (W m^{-2}) for a 50% partly cloud pixel with in-cloud optical depth = 5 When Visible-Channel based Optical Depth is Used

The magnitude of irradiance biases gets larger as SZA increases.

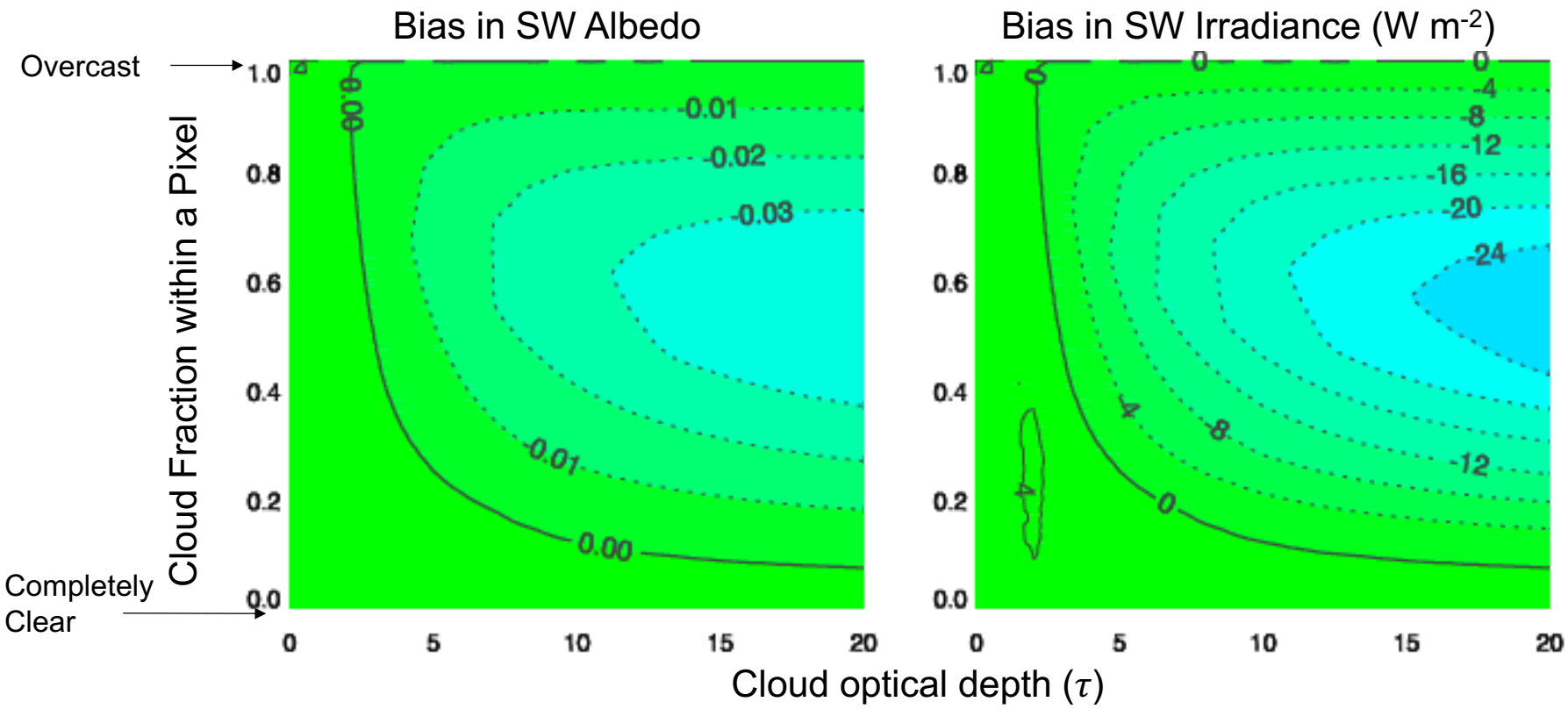
τ retrieval is not possible at sun glint region

SW BB Albedo Biases for a Fixed Viewing/Solar Geometry (SZA=60º, VZA=10º, RAA=90º)



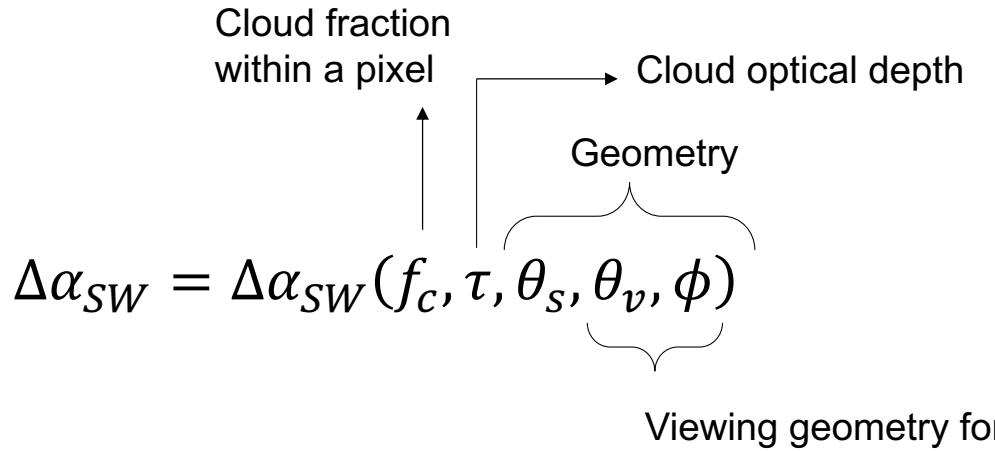
The bias increases with τ. For the fixed τ, the bias is the largest for f_c = 0.2 – 0.8.

SW BB Albedo Biases for a Fixed Viewing/Solar Geometry (SZA=60º, VZA=70º, RAA=90º)



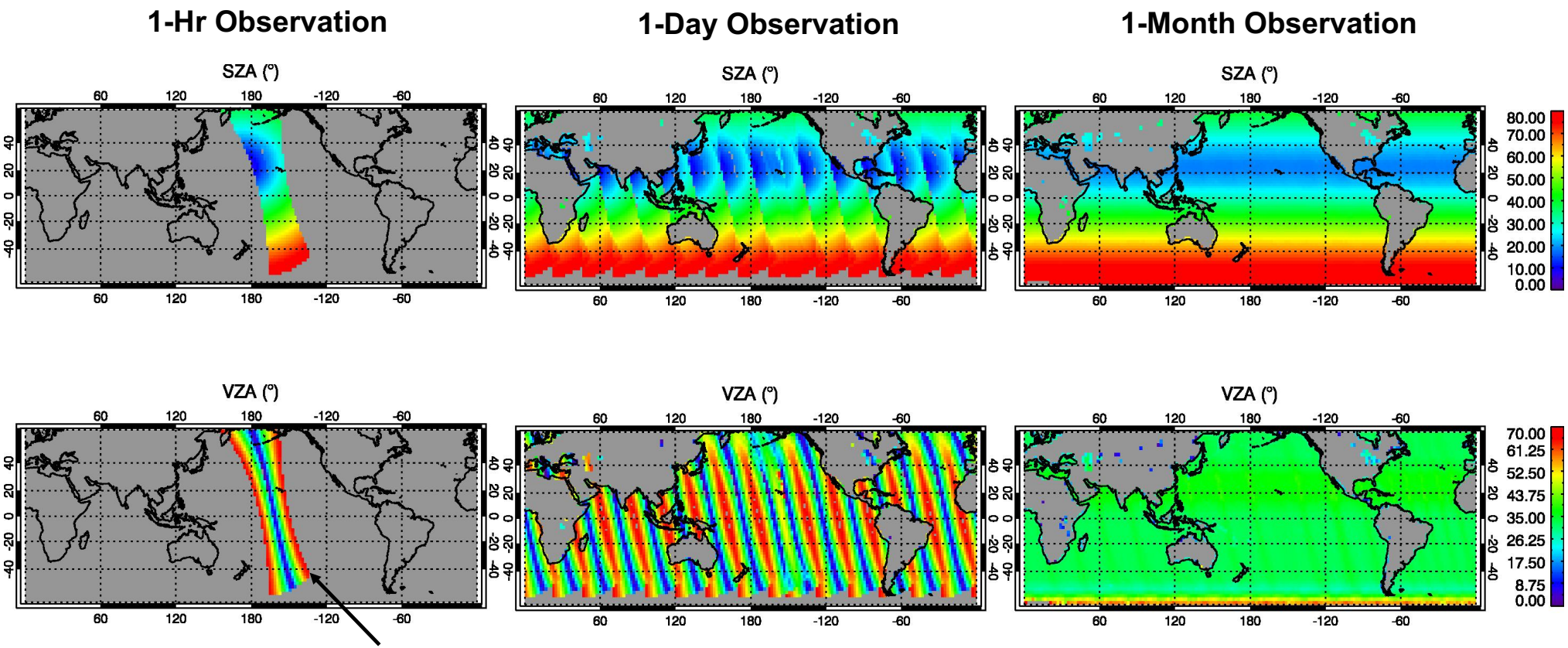
The bias increases with τ. For the fixed τ, the bias is the largest for f_c = 0.2 – 0.8.

Therefore, SW broadband albedo bias ($\Delta\alpha_{SW}$) due to partly cloudy MODIS pixels can be expressed as



- The magnitude of SW albedo biases gets larger for f_c = 0.2 – 0.8, while the bias is zero for completely clear (f_c =0) or overcast (f_c =1) pixels.
- The SW biases increase with cloud optical depth.
- As the solar zenith angle increases, the magnitude of SW albedo/irradiance biases increases.
- For small viewing zenith angles (θ_v), SW albedo biases tend to be positive. For large viewing zenith angles (θ_v), SW albedo biases tend to be negative.

Solar and Viewing Geometry for CERES Observations (July 2013)



Min VZA = 0°: Likely + SW Bias
Max VZA = 65°: Likely – SW Bias

Monthly averaged VZA < 50°, meaning that monthly mean SW bias is likely positive.

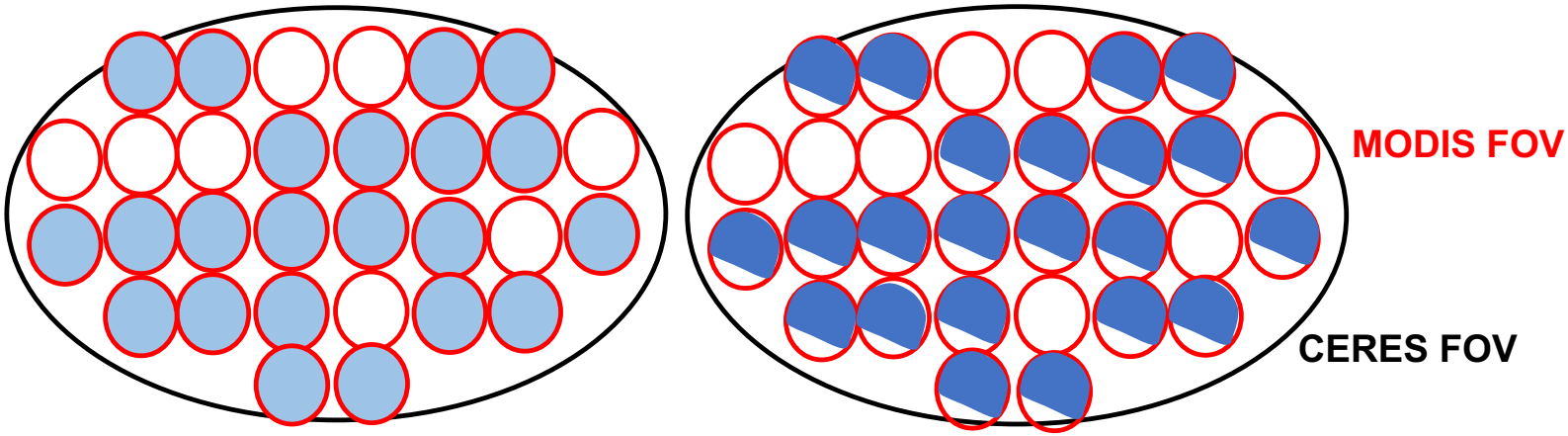
Uncertainty Estimates of SW TOA Irradiance Computations due to Partly Cloudy Pixels

- Because it is difficult get sub-grid scale information for the MODIS pixel, we simply assume partly cloud pixels when the MODIS cloud coverage within one CERES FOV is small.
- For example, when the MODIS low cloud coverage within a CERES FOV < 80%, it is assumed that the cloudy MODIS pixel is partly (80%) cloudy, and then the cloud optical depth is adjusted to keep the visible reflectance the same. By assuming partly cloudy pixels, TOA irradiance would be changed and the changed amounts (ΔF) (W m^{-2}) can be considered as impacts of partly cloud pixels.

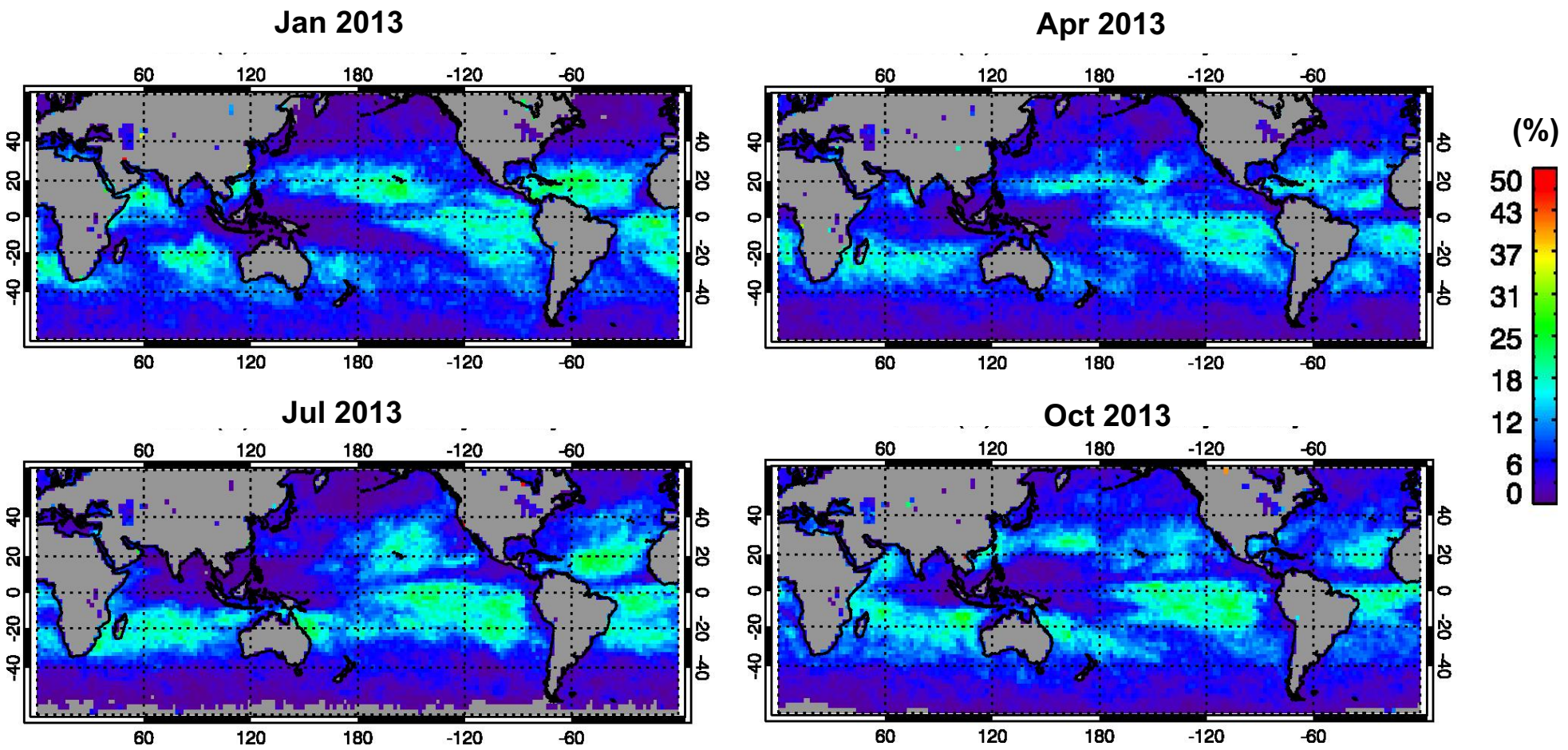
In-Cloud optical depth	$\tau_{overcast}$	<	τ_{partly}
Visible channel radiance	$I_{overcast}$	=	I_{partly}
SW broadband irradiance	$F_{overcast}$	≠	F_{partly}

$\Delta F = F_{overcast} - F_{partly}$

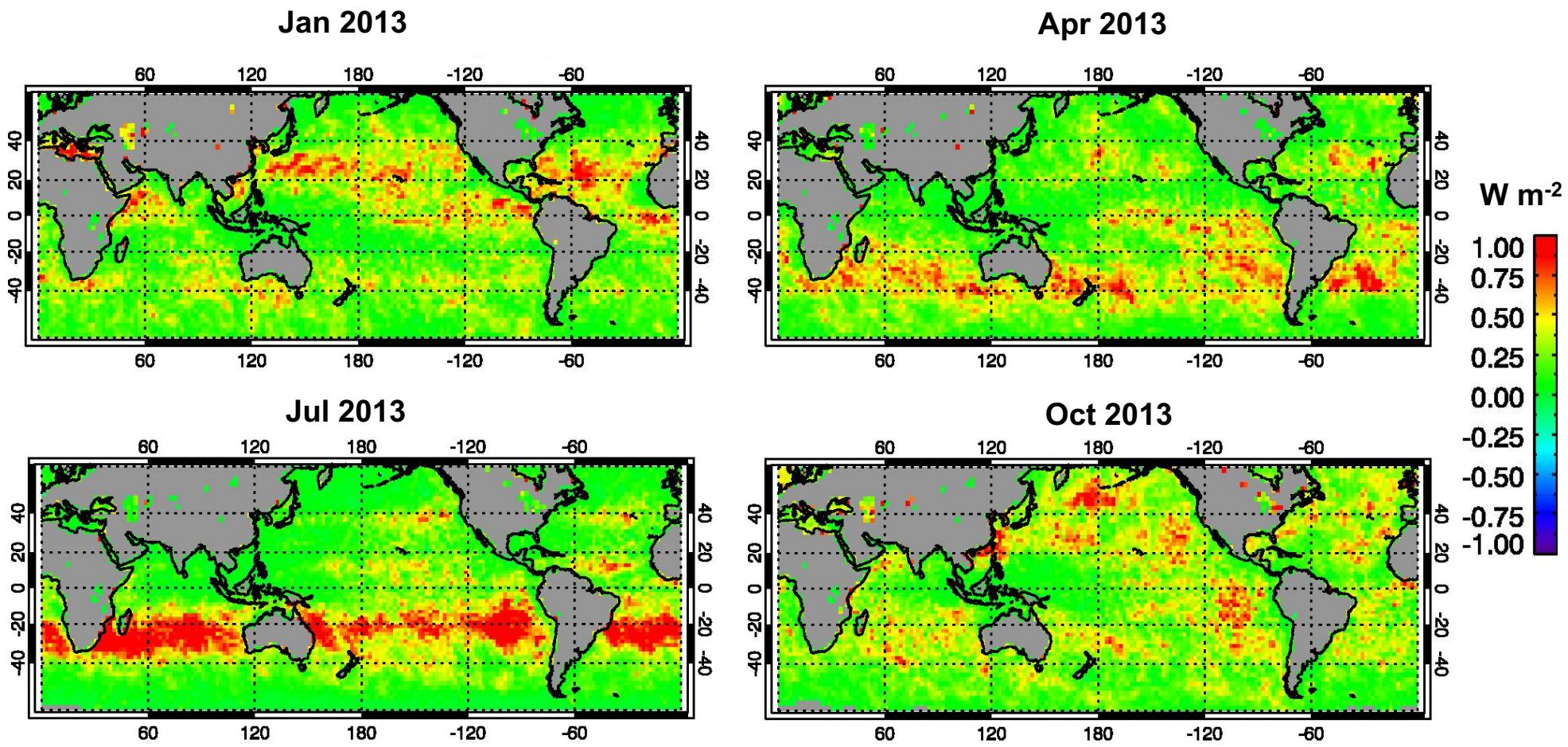
"Uncertainty of F due to partly cloudy pixels"



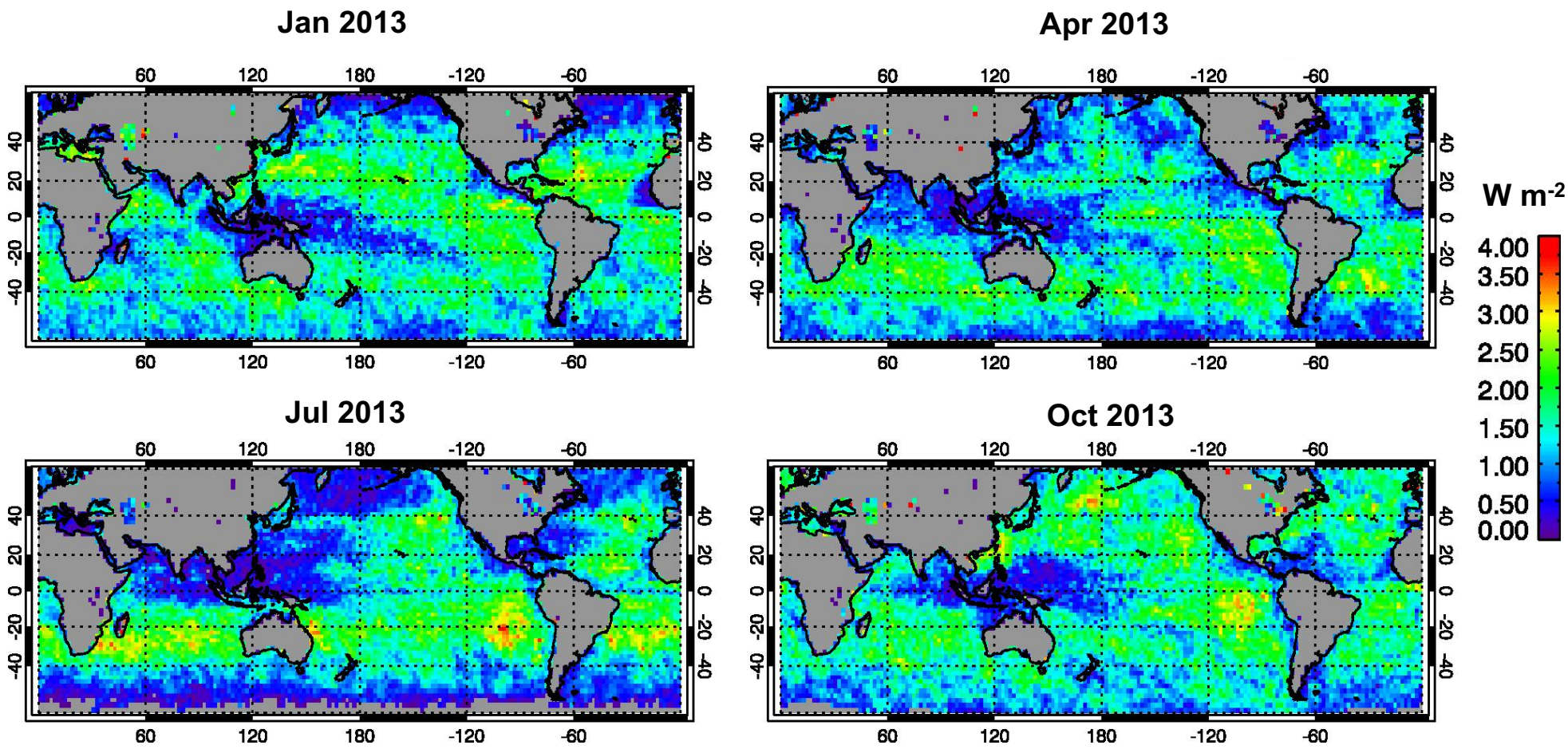
Area (%) Assumed as 80% Partly Cloudy Pixels
When the MODIS Low Cloud Coverage within a CERES FOV < 80%



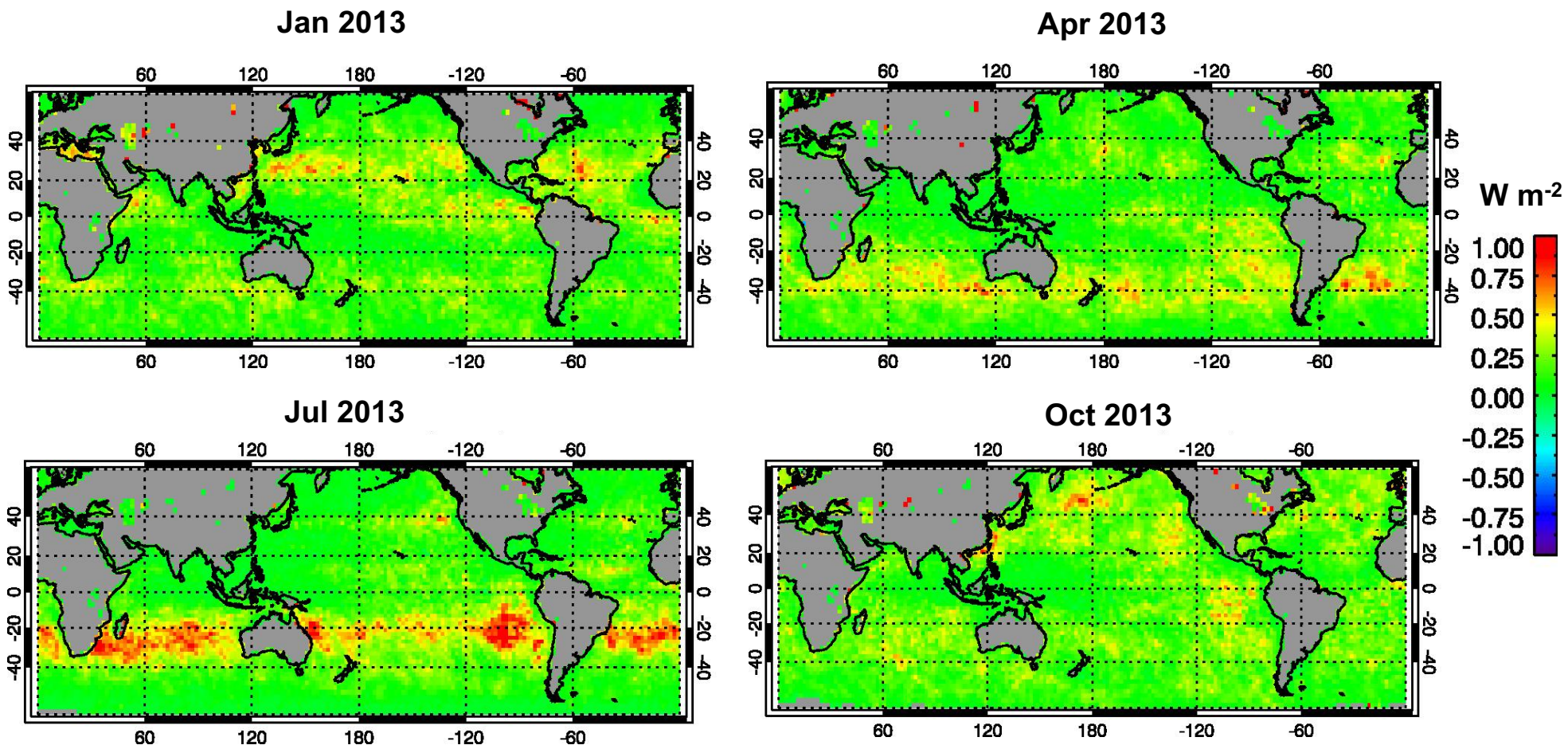
Monthly Mean of TOA Irradiance Changes ($\Delta F = F_{overcast} - F_{partly}$) by Assuming 80% Partly Cloudy Pixels for MODIS Low Cloud Coverage within a CERES FOV < 80%



RMS of TOA Irradiance Changes ($\Delta F = F_{overcast} - F_{partly}$) by Assuming 80% Partly Cloudy Pixels for MODIS Low Cloud Coverage within a CERES FOV < 80%



Monthly Mean of TOA Irradiance Changes ($\Delta F = F_{overcast} - F_{partly}$) by Assuming 90% Partly Cloudy Pixels for MODIS Low Cloud Coverage within a CERES FOV < 90%

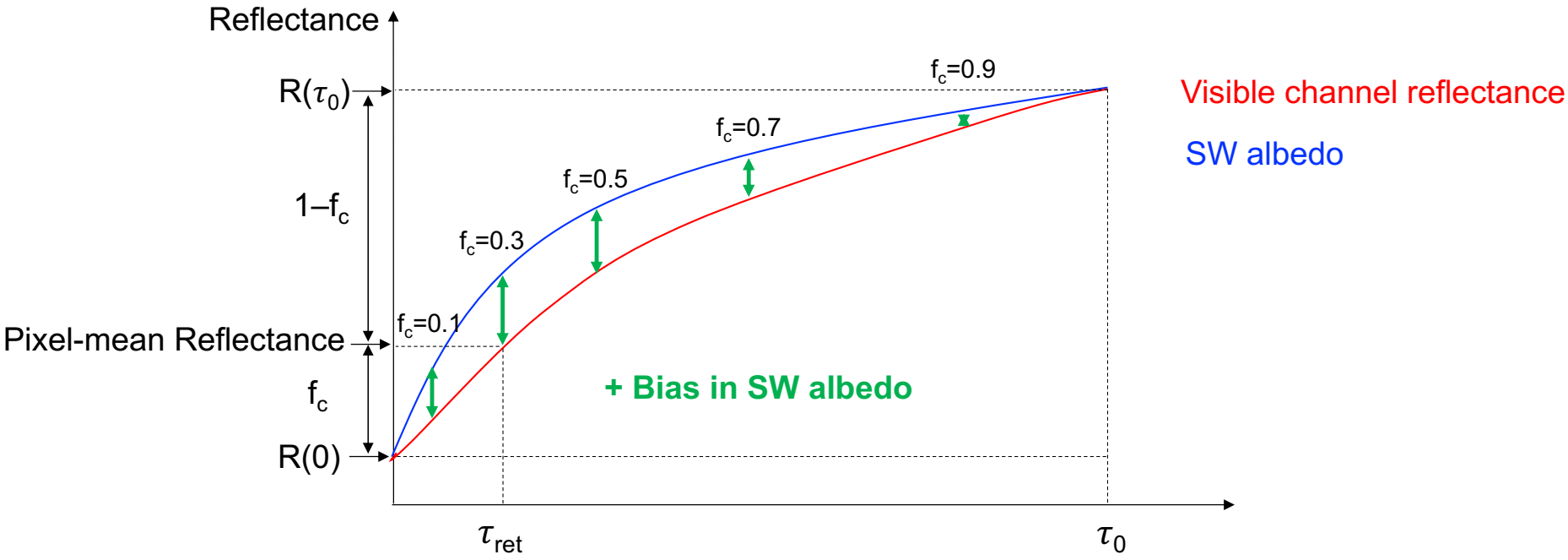


Summary and Conclusions

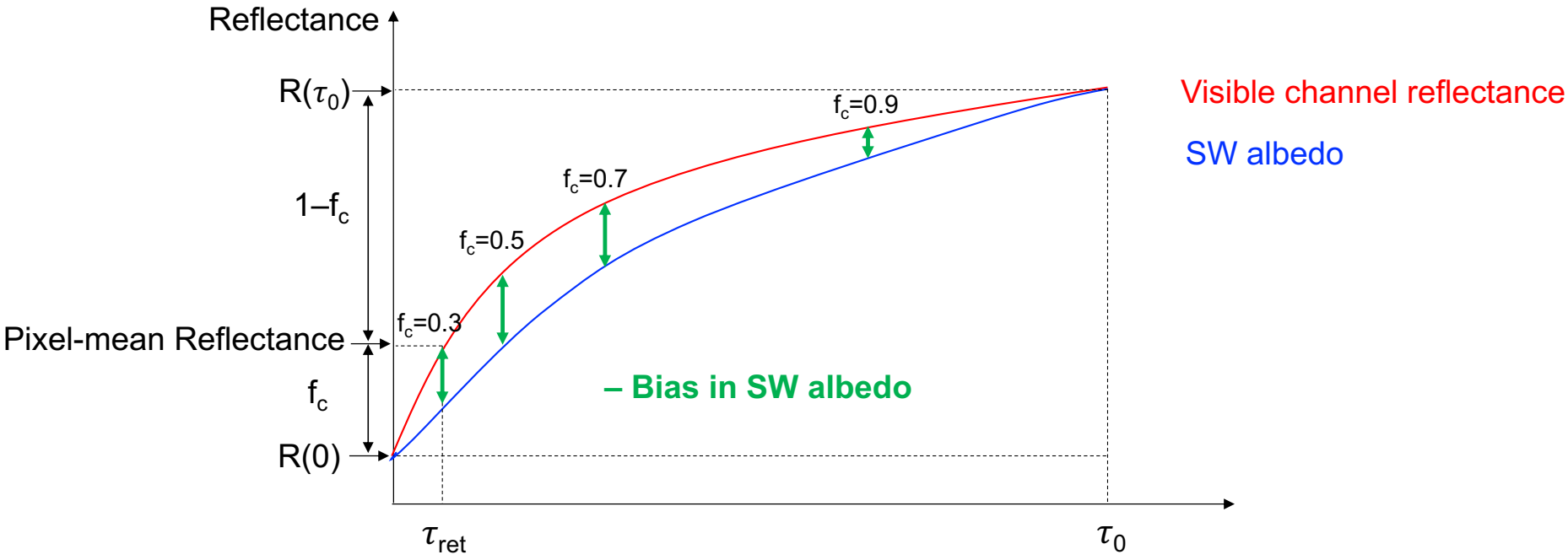
- When the pixel is partly cloudy, retrieved optical depth is biased. If we use the visible-channel-retrieved optical depth for SW irradiance computations, biases are expected because the SW albedo function has a different shape from that of visible bidirectional reflection function.
- The SW irradiance biases are generally positive for small viewing zenith angles ($\lesssim$ 50–60°) and negative for large viewing zenith angle ($\gtrsim$ 50–60°). In addition, the biases increase with SZA.
- For the fixed geometry, and the SW irradiance biases are the largest when the cloud fraction is between 0.2 and 0.8. In addition, the biases increase with cloud optical depth
- When we assume 80% partly cloudy pixels if MODIS cloud coverage within a CERES FOV < 80%, the monthly mean biases up to 1 W m^{-2} are appeared in broken cloud regions. Further investigation is needed to detect of partly cloudy pixels and find actual cloud fraction within the pixels.

Thank You for Your Attention!

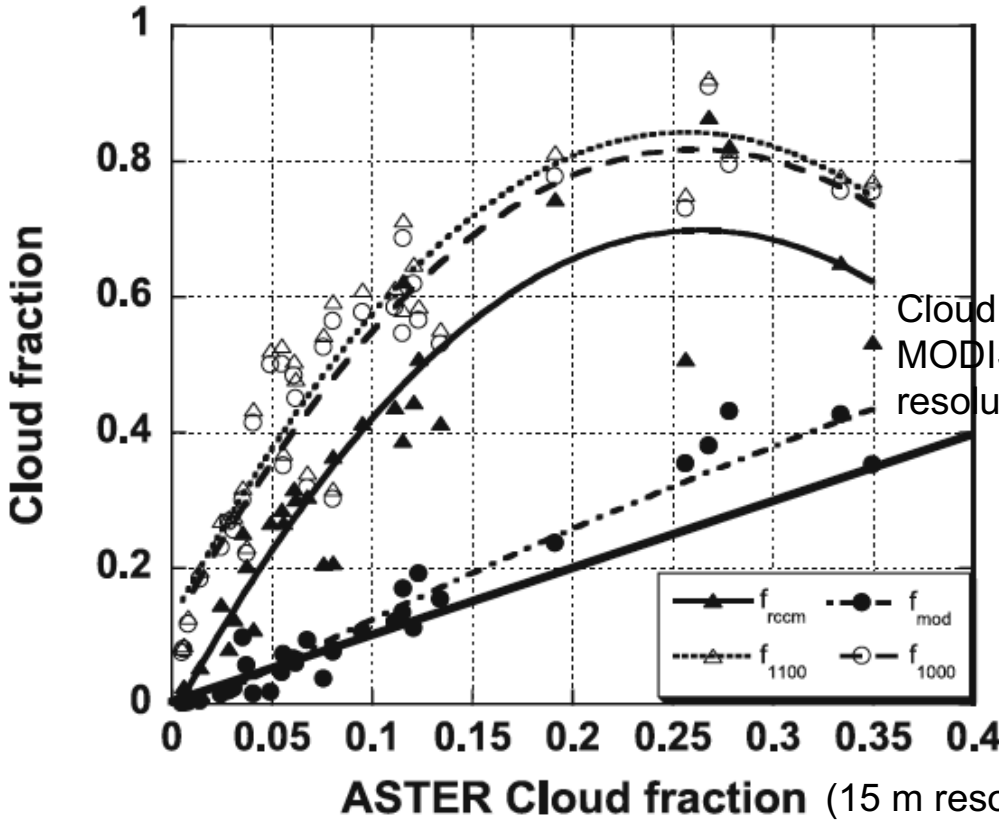
Positive Biases in SW Albedo: Visible reflectance function is more linear than SW albedo function



Negative Biases in SW Albedo: SW albedo function is more linear than visible reflectance function.



Cloud Fraction for Trade Wind Cumuli from High-Resolution Instruments



Cloud fraction from MODIS: 1 km resolution (MOD35)

MODIS cloud fraction is larger than higher-resolution of ASTER cloud fraction, suggesting that MODIS cloudy pixels are not completely overcast.

(Zhao and Di Girolamo, 2006)